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DISRUPTION OF SULFUR METABOLISM IN PLANTS AFFECTED BY AIR POLLUTION

[Narusheniye sernogo obmena v rasteniyakh pod vliyanyem zagryazneniya atmosfernogo vozdukha]

by

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Oaks, maples, lilacs, and other plants growing in air polluted by sulfur dioxide [7446-09-5] accumulated > normal amts. of sulfur [7704-34-9] in their leaves. Greater amts. of S accumulated in the leaves of the plants during a dry year than during a year with heavy rainfall. Possibly the response of the plants to dryness also increases its resistance to SO_2poisoning.

The physiological role of sulfur in plants is determined by the high biochemical activity of its compounds. Disruption in production and ratios of sulfur-containing compounds reduces the resistance of plants to unfavorable environmental conditions. Different factors can be the cause of the disruptions, for example, change in the ionic composition of the cellular medium, temperature increase and

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reduction, disruption of water supply conditions, ionizing radiation, poisons and sulfur nutrition level [1-6].

Under the conditions of the industrial Donbas, the most significant of the factors enumerated are disruption of plant sulfur nutrition, as a result of heavy contamination of the air and soil with industrial discharges [7], water metabolism, as well as overheating of the plants [8]. We have studied changes in sulfur content and resistance of plants with respect to these factors.

In the test section, the maximum single concentration of sulfur dioxide exceeded the maximum permissible by 6.2 times. A section with a radius of 35 km, in which there are no industrial enterprises, was taken as the control.

Samples of leaves and roots, after collection, were washed with distilled water. Determination of the total sulfur content in the test samples was made by blow-pipe analysis, with addition of nitric acid and hydrogen peroxide and subsequent precipitation of barium chloride with sulfuric acid [9]. The resulting data were converted to a SO_4 basis.

The amount of sulfur in the leaves in the control section varied, fluctuating from 0.3 to 1.1% in different species (Table 1).

In the first half of the growing period, the sulfur content in the leaves in the control section is practically unchanged (0.3-0.4%), and it even decreases in the black locust. Plants absorb sulfur during the entire growing period [10], but during the intensive growth period, it does not accumulate in the leaves. By the end of growth, the sulfur content increases, and the greatest amount of it is noted in privet, lilac, elm and Norway maple, and the least, in smoke-tree, birch, silver maple and catalpa.

Table 1

Sulfur Content in Plant Leaves (in % of Dry Weight)

a Растение	b Опыт			c Контроль		
	e 19.V	e 22.VII	e 1.IX	e 19.V	e 22.VII	e 1.IX
Белая акация . . . . . f	0,7	0,8	0,9	0,7	0,3	0,6
Дуб черешчатый . . . g	0,4	0,8	0,9	0,4	0,3	0,7
Каштан конский . . . h	0,4	0,9	1,2	0,4	0,3	0,5
Клен остролистный . . i	0,7	0,8	1,7	0,4	0,4	0,8
Липа мелколистная . . j	0,8	1,8	1,9	0,4	0,4	0,5
Береза бородавчатая . . . k	—	—	1,4	—	—	0,4
Бирючина обыкновенная . l	—	—	1,9	—	—	1,1
Вяз перисто-ветвистый . . m . . .	—	—	0,8	—	—	0,9
Гледичия трехколючковая . n . . .	—	—	0,8	—	—	0,6
Катальпа бигнониевидная . o . . .	—	—	0,9	—	—	0,4
Клен серебристый . . . . p	—	—	0,8	—	—	0,4
Клен ясенелистный . . q	—	—	0,9	—	—	0,5
Сирень обыкновенная . r	—	—	1,3	—	—	1,0
Скумпия . . . . . s	—	—	1,2	—	—	0,3
Черемуха поздняя . . . t	—	—	0,7	—	—	0,7
Шелковица белая . . . u	—	—	0,9	—	—	0,4

Key: a. plant
b. test
c. control
e. day and month
f. black locust
g. pedunculate oak
h. horse chestnut
i. Norway maple
j. small-leaved lime
k. common birch
l. common privet
m. feather-branched elm
n. common honey locust
o. bignonia catalpa
p. silver maple
q. ash-leaved maple
r. common lilac
s. smoke tree
t. black cherry
u. white mulberry

[Translator's note: commas in tabulated figures are equivalent to decimal points].

A different picture is observed in the test section. An increase in sulfur dioxide content in the air leads to accumulation of sulfur in the leaves, with the content of it being considerably higher at the beginning of the growing period. By the end of summer, the difference increases still more, and it amounts to (in %): in linden, 1.4;

birch, 1.0; Norway maple and smoke tree, 0.9. Moreover, a selective ability of plants is observed here to accumulate sulfur compounds in the leaves. Thus, in the oak, honey locust and black locust under polluted conditions, the sulfur content increases by only 0.2-0.3%, and it remains unchanged in the elm and black cherry.

The accumulation of sulfur in the leaves is apparently explained by both different gas-absorbing capacities and intensive efflux and redistribution of the excess sulfur in perennial elements. Study of the sulfur content in the roots, leaf stalks and blades has shown that, in the control, the sulfur content in the roots and leaf stalks of 5 species investigated are approximately identical, but less in absolute value than in the leaves.

In the test section, the sulfur content in the stalks and roots increases negligibly in the locust, oak and maple, which is evidence of the absence of intensive efflux of sulfur from the leaves in them. Besides, the sulfur content in the locust and oak, as has been noted above, scarcely increases, while it more than doubles in maple leaves (Table 2).

Table 2

Sulfur Content in Roots and Leaves of Plants (in % of Dry Weight) on 1 October

a Растение	b Контроль			c Опыт		
	d корень	e черешок	f листовая пластинка	d корень	e черешок	f листовая пластинка
Белая акация . . g. . .	0,5	0,5	0,6	0,5	0,5	0,9
Дуб черешчатый . h. . .	0,3	0,3	0,7	0,5	0,4	0,9
Каштан конский . i. . .	0,3	0,3	0,5	1,0	1,5	1,2
Клен остролистный . j. . .	0,3	0,3	0,8	0,4	0,3	1,7
Липа мелколистная . k. . .	0,2	0,4	0,5	1,1	1,2	1,9

Key: a. plant
b. control
c. test
d. root
e. leaf stalk
f. blade
g. black locust
h. pedunculate oak
i. horse chestnut
j. Norway maple
k. small-leaved lime

In the chestnut and linden, together with a considerable increase in accumulation of sulfur in the leaves, the content of it in the leaf stalks and roots increases sharply, which is evidence of an intensive efflux of it from the leaves.

As is evident, the gas-absorbing capacity is least of all in the black locust and oak, and highest in the chestnut and linden. The maple occupies an intermediate position, but a considerable accumulation of sulfur is noted in the leaves, as a consequence of the low efflux.

Excess accumulation of sulfur in plants leads to damage to them [8, 11], which is confirmed by analysis of damaged and undamaged leaves (Table 3).

Table 3

Sulfur Content in Plant Leaves (in % of Dry Weight)

a Растение	b Дата	c Листья	
		d поврежденные	e неповрежденные
Каштан конский f.	24.VII	0,9	0,7
	1.IX	1,2	0,6
Липа мелколистная g.	24.VII	1,8	1,2
	1.IX	1,9	1,4
Клен остролистный h.	24.VII	0,8	0,7
	1.IX	1,7	0,8
Катальпа бигнониевидная i. . . .	1.IX	0,9	0,7
Клен ясенелистный . . . j	1.IX	0,9	0,9
Тополь канадский . . . k	1.IX	1,2	1,2

Key: a. plant
b. date [day and month]
c. leaves
d. damaged
e. undamaged
f. horse chestnut
g. small-leaved lime
h. Norway maple
i. bignonia catalpa
j. ash-leaved maple
k. Canadian poplar

In the ash-leaved maple and Canadian poplar, the sulfur content is high, but identical, in damaged and undamaged leaves. In these plants, which are resistant to air pollution by sulfur dioxide [12], damage to the leaves is caused by the effect of drying out and high temperatures during the dry period.

In the chestnut, linden and Norway maple, damage to the leaves under the test conditions was very much higher than in the control. The simultaneous effect of sulfur dioxide and drought facilitates heavier damage to the less drought-resistant plants. For example, in arid 1968 (April-August precipitation 56% of normal), damage to the leaves began earlier, but the total sulfur content (Table 4) was higher than in the more favorable 1969 (in the same period, precipitation was 108% of normal).

Table 4

Sulfur Content in Plant Leaves in Different Years (in % of Dry Weight

a Растение	b Опыт		c Контроль	
	1968 г.	1969 г.	1968 г.	1969 г.
d Июнь				
Белая акация . e	0,6	0,7	0,8	0,7
Дуб черешчатый . f	1,5	0,5	0,5	0,3
Каштан конский . g	1,3	0,5	0,9	0,4
Клен остролистный . h . .	1,6	0,7	0,8	0,4
Липа мелколистная . i . .	1,4	0,8	0,8	0,4
j Август				
Белая акация . e	1,7	0,9	0,4	0,6
Дуб черешчатый . f	2,6	0,9	0,6	0,7
Каштан конский . g	2,8	1,2	1,1	0,5
Клен остролистный . h . .	3,0	1,7	1,0	0,8
Липа мелколистная . i . .	2,5	1,9	0,8	0,5

Key: a. plant
b. test
c. control
d. June
e. black locust
f. pedunculate oak
g. horse chestnut
h. Norway maple
i. small-leaved lime
j. August

Strengthening of the protective reactions of plants, in response to the effects of the dry season leads to an increase in overall nonspecific resistance of the organism to both the effect of unfavorable climatic factors and to atmospheric pollution. Damage to plants in 1969 was observed much later, occurred with a lower sulfur content in the leaves and was caused by a sharp increase in air temperature and almost complete absence of precipitation in this period.

Conclusions

Pollution of atmospheric air with sulfur dioxide increases the sulfur content in the majority of plants. The level of accumulation of it under the effect of pollution differs in different species. The sulfur content is determined by both the gas-absorbing capacity of the leaves and the efflux of it to other elements. The toxic level of sulfur content in the leaves depends on the species of plant and the meteorological conditions during the growing period.

The effect of gradually increasing moisture deficit and high temperatures leads to strengthening of the protective reactions of the organisms, and damage to the leaves is observed at a high absolute sulfur content; during wet years, with an abrupt onset of the dry season, damage is observed with a lower sulfur content.

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